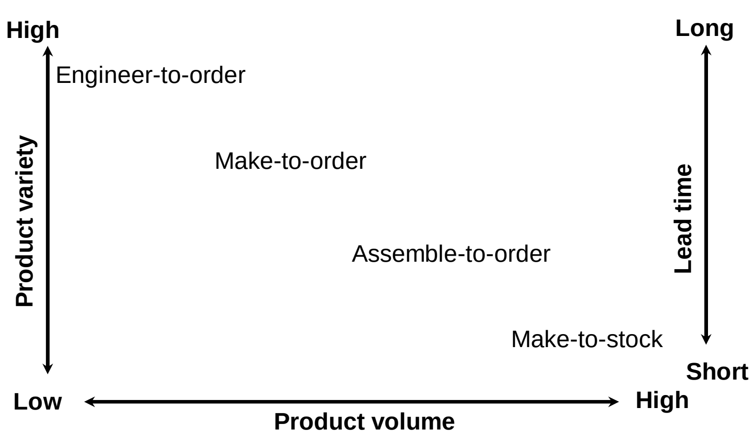
Defining Execution and Control Systems

References: Jacobs et al., *Manufacturing Planning and Control for Supply Chain Management*, APICS/CPIM Certification ed. chap. 11, 17; Dennis, *Lean Production Simplified*, 2nd ed., chap. 5; Slack et al., *Operations and Process Management*, 2nd ed., chap. 4.

Introduction

- Manufacturing environments
- Production processes
- Process layouts
- Requirements for execution and control activities

Manufacturing Environments



Defining Execution and Control Systems

In this section, we review the factors, or principles, underlying the choice of execution and control systems. Appropriate choices should fit an organization's

- manufacturing environment
- production processes
- process layouts
- requirements for detailed execution and control activities.

Manufacturing Environments

As we pointed out in the discussion of the manufacturing planning hierarchy, the choice of manufacturing environments is a strategic and business planning decision that sets the direction for MPC. The visual differentiates the generic types of manufacturing environments in terms of volume and variety characteristics, as summarized below.

Manufacturing environments		
Volume	Variety	
Low	High	Engineer-to-order (ETO). Because customer product specifications require a unique design, product volume is low. Generally, no two products are alike, therefore product variety is high. There could be many variations of the product.
Low-medium	Medium	Make-to-order (MTO). Products are neither high enough in volume nor medium to low enough in variety to justify producing some components in advance as in assemble-to-order (ATO).
Medium-high	Low-medium	ATO. Products are high enough in volume with adequate variety to justify making components and subassemblies in advance and performing end-item final assembly when the order is received to reduce delivery lead time.
High	Low	Make-to-stock. Products are high enough in volume of sales and low enough in variety to justify assembly prior to receipt of an order.

How do manufacturing environments reflect customer lead-time expectations?

____

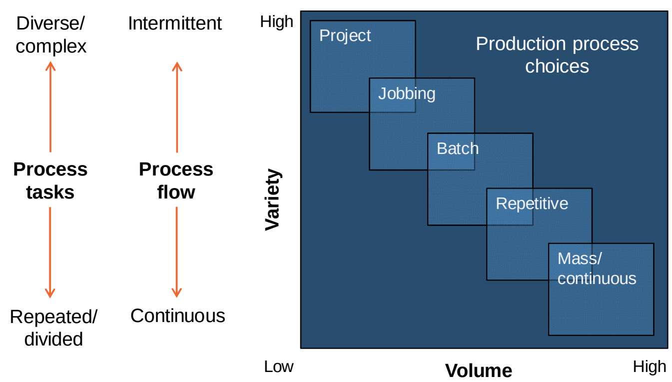
____

What factors can cause a company to alter or adopt a different manufacturing environment?

____

____

Process Types: Manufacturing



Source: *Operations and Process Management*, Slack et al., 2nd ed., 2009; reprinted by permission of Pearson Education

1 • 18

Production Process Choices

Manufacturers have a choice from among five generic production processes. Arrayed against the same volume-variety matrix, the choices bear a direct relationship to the manufacturing environments shown in the previous visual. The choice of process type, as we will discuss later, subsequently affects the choice of execution and control systems. The following table summarizes the five basic process types.

Production Process Choices	
Project manufacturing processes	This usually is associated with ETO manufacturing environments and typically involves highly customized discrete products of wide variety made one at a time. Resources generally are dedicated to individual tasks. The process involves many unique process tasks and highly intermittent flow of materials. It often is used in shipbuilding, house construction, oil well construction, and in service industries such as motion picture production and information technology application software implementation.
Intermittent/job shop production processes	This is associated with MTO manufacturing environments. Resources (equipment, labor) are shared among tasks but achieve different results for different discrete products. It typically involves very low repetition and many products can be one-of-a-kind. Process maps would show a wide variety of routings. Worker skill requirements are high, as in project process, but work is more predictable. The process often is used in specialist tool making, furniture restoration, make-to-measure tailoring, and printing.
Batch production processes (job shop and flow)	This is similar to intermittent processes, but variety is lower and volume is higher than MTO and not as high as in MTS mass/continuous production environments. Small batch process production only slightly differs from jobbing, but large batch production (batch flow) is similar to mass/continuous production processes. This process often is used in manufacturing machine tools, component parts that go into mass-produced assemblies (such as automobiles), clothing lines, and pharmaceuticals.
Repetitive production processes	Associated with MTS and ATO manufacturing environments. Production activities for discrete products are repetitive and predictable. The process involves very high volume with little effective variety. Product variants on an automobile assembly line, for example, do not affect the basic process of production. The process also is used in consumer durables (refrigerators) manufacturing, most food processing, beverage bottling, and compact disc production.
Mass/continuous production processes	Products flow continuously from one part of the process to another and are not discrete. Examples include chemicals, fertilizers, steel, electricity, and glass. This could involve even higher volume and lower variety than the repetitive production process. The process is even more capital intensive and less flexible than the repetitive production process.

Source: Slack et al., *Operations and Process Management*, 2nd ed., chap. 4

What is the difference between discrete and non-discrete products?

____

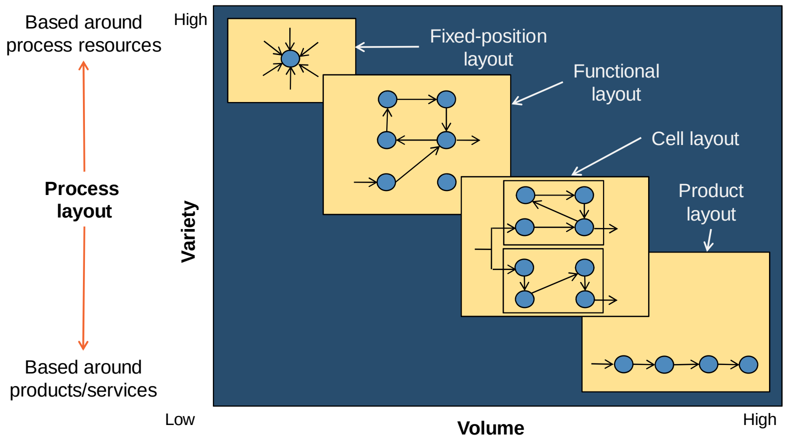
____

How does a mass/continuous production process differ from a repetitive production process?

____

____

Process Layouts



Source: *Operations and Process Management*, Slack et al., 2nd ed., 2009; reprinted by permission of Pearson Education

1 • 19 © APICS Confidential and Proprietary

Process Layouts

There are a few basic principles relating to process layout, which include the following:

- It is determined to a large extent by volume and variety characteristics.
- Layout should facilitate product flow when variety is low and volume is high.
- Product flow may not be important when volume is very low and infrequent.

The four process layout types in the visual correspond to the position of production processes on the same volume-variety matrix.

Layouts	Description
Fixed-position layout	♦ The product that is being produced is stationary. ♦ Equipment and machinery, materials, labor, information, and plant move to the production or service site. ♦ The layout is used in building power generators and communications satellites.
Functional layout	1. Transforming resources dominate the layout decision. 2. Materials and semifinished products move through work centers that provide the necessary transformation. Routings differ for different products; the flow pattern is complex. 3. The layout is used in machining of tools and parts for aircraft engines.
Cell layout	1. This is an alternative to the complex flow of a functional layout. 2. Resources for production processes are grouped into a cell or manufacturing unit in which all transforming resources are located to facilitate flow. 3. The output may flow to another cell or back into a functional layout. An example would include work stations that are dedicated to assembly of high-quality components for computer manufacturing.
Product layout	a. The location of equipment and workers accommodates the flow of product in high-volume operations. b. A linear or dedicated *repetitive flow* layout is used for discrete product assembly; for example, with automobiles and consumer-packaged goods. c. A *continuous flow* layout facilitates the processing of fluids, powders, and other bulk items.

When variety is low and volume is high, why is it advantageous to position resources such as technology and workers to accommodate a flow manufacturing process?

____

____

How do the four process layouts shown in the visual differ in terms of facilitating process flow?

____

____

Execution and Control: Selection Factors

Category	Batch processes	Flow processes		
Process type	Job shop or Intermittent	Batch flow	Repetitive	Mass/ continuous
Layout	Functional (process)	Product	Product	Product
Routing	Product specific	Product specific	Fixed	Fixed
Scheduling	Operations scheduling	Operations scheduling or rate-based scheduling	Production scheduling: rate-based	Production scheduling: rate-based
Control	MRP/PAC	MRP/PAC	MRP/PAC	MRP/process flow scheduling
Transaction requirements	Very high	Medium	Low	Low
Productivity tools	Lean/TOC/six sigma	Lean/TOC/six sigma	Lean/TOC/Six sigma	Lean/TOC/six sigma

1 • 20

Batch Versus Flow Process Implications

The major process choices shown in Visual 1-20 can be characterized as either batch or flow processes. The implications of this differentiation are as follows.

Batch Process

The batch process or processing is embodied in job shop or intermittent production. Two definitions based on the *APICS Dictionary* are relevant here.

- Batch processing—A manufacturing technique in which parts are accumulated and processed together in a lot
- Intermittent production—A form of manufacturing in which the jobs pass through the functional departments in lots, and each lot may have a different routing

The important characteristics of job shop or intermittent batch processes are shown in the visual. Note that the scheduling technique used in batch processing is called *operations scheduling*. Operations scheduling assigns starting or completion dates to operations at general purpose work centers for the routings required by specific work orders.

What do the characteristics of batch processes imply about production lead time, WIP levels, and production reporting and status control intensity?

____

____

Flow Process

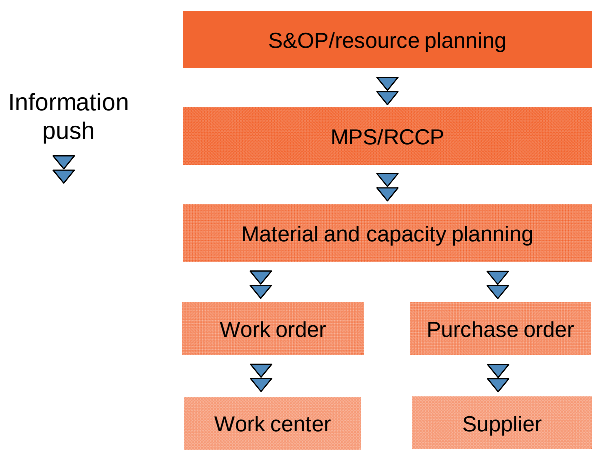
Three different process types fall into the flow process category: (1) batch flow (as opposed to job shop batch process), (2) repetitive production, and (3) mass/continuous production. The basic characteristics of flow processes are as follows:

- Machines and operators handle a standard and usually uninterrupted material flow.
- Machine, bench, and assembly line layouts are designed to facilitate product flow (product layout).
- Operators generally perform the same operations for each production run.
- A flow shop often is referred to as a repetitive production shop for discrete products; as having a continuous flow for high volume non-discrete products such as gasoline, steel, fertilizer, and glass; and as accommodating the continuous flow of a lower volume of non-discrete products over a product layout, such as chemicals and pharmaceuticals manufactured in batches or lots.
- Scheduling generally is rate-based, and products generally are manufactured in bulk.
- Execution and control transaction requirements are low compared to job shop batch processes.

Principles of Push Systems

- Rely on MPC to plan production priorities and capacity.
- For batch processes
  - create detailed time-phased schedules.
  - release and push work orders through operations based schedules.
  - use MRP-based production activity control
  - maximize capacity utilization.
- For flow processes
  - produce to rate-based schedules.
  - maximize rate of product flow.
  - create finished goods inventory as necessary.

Push Model



Push Versus Pull Principles

It is important at this point in the course to understand the differences between push and pull systems in executing operations. Later in the course you will be able to appreciate how these two systems differ in terms of

- authorizing and releasing work
- managing the resources needed to accomplish the work.

Push Systems

Principles

A push execution system, which we also refer to as an MRP-based execution system, is based on the following principles:

- It relies on MPC systems to plan production priorities (what is needed and when) and capacity.
- For batch processing operations,
  - it creates detailed time-phased schedules in advance
  - it releases and pushes shop-floor orders through operations at requisite work centers
  - it relies on MRP-based production activity control processes that authorize production quantities, routings, and due dates
  - it maximizes capacity utilization.
- For flow manufacturing process operations,
  - it produces to rate-based schedules based on hourly or daily component flow rates
  - it moves material quickly and without interruption through manufacturing, maximizing the rate of product flow
  - it creates finished goods inventory as necessary.

Push model

The visual illustrates the information flow in a push system. To plan and control work, information is pushed through the planning and execution phases of MPC

- from S&OP to master scheduling
- from master scheduling to material planning
- from material planning to execution activities.

Information pushed to execution activities is in the form of

- work orders to work centers in job shops to produce released items and quantities
- rate-based schedules to authorize the start of flow manufacturing processes
- purchase orders or release authorizations as necessary to suppliers.

Principles of Lean

- Produce products only to customer orders.
- Level demand so that work may proceed smoothly.
- Link processes to customer demand through visual tools.
- Maximize the flexibility of people and machinery.

1 • 23

APICS

Pull Systems

As mentioned earlier, in a push or MRP-based system, orders are released and pushed through work centers to execute the MPS for batch processes. For MRP-based flow manufacturing processes, rate-based schedules are released to execute the MPS.

Pull manufacturing systems are known as lean systems. As discussed below, they are based on an altogether different set of principles with respect to ECO.

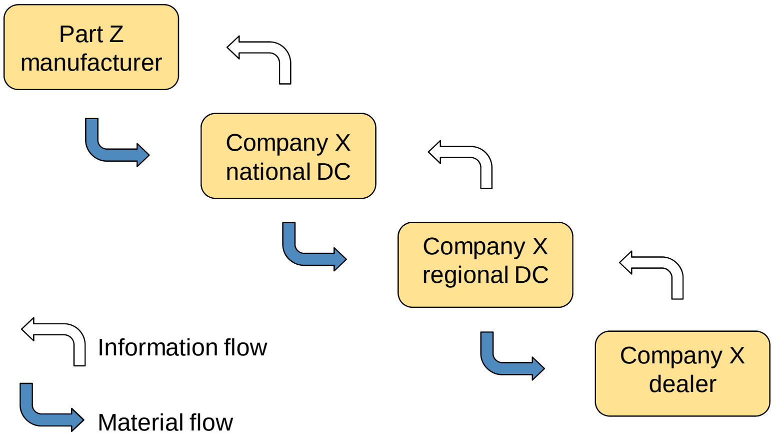
Principles

The visual summarizes some basic principles of lean. These principles relate to important characteristics of lean that will be discussed in a later section in this session.

Four key principles are as follows:

1. Produce products only to customer orders—This reflects the *demand-pull* basis for lean. Lean strives for a condition in which nothing is produced unless a customer has ordered it.
2. Level demand so that work may proceed smoothly—Lean works best when relationships with customers are based on formal or informal partnership arrangements. Such arrangements enable supply-chain partners to coordinate their production rates so that demand for and production of components or finished goods is level and continuous.
3. Link processes to customer demand through visual tools—Customers are both internal and external. Lean systems are designed to enable visual management of the shop floor. Dependence on information technology and MRP-based shop floor scheduling and control applications to authorize and control operations, as in push systems, is considerably reduced.
4. Maximize the flexibility of people and machinery—The use of cellular manufacturing techniques, which we will describe later in this course, accommodates this principle.

Pull System Model



Source: *Lean Production Simplified*, Dennis, 2nd ed., 2007

1 • 24 © APICS Confidential and Proprietary

Pull model

Let's reinforce the basic concept of pull in lean systems. The visual illustrates the pull concept based on an order for the replacement of an automobile part (Z) by a dealer of Company X.

Step 1	Dealer X replaces part Z on a customer's automobile, then sends a signal to Company X's regional parts distribution center that there is a "hole" in the dealer's inventory of part Z.
Step 2	Company X regional parts distribution center sends replenishment part Z to the dealer, then sends a signal to its national parts distribution center for the replenishment of part Z in its inventory.
Step 3	Company X national parts distribution center replenishes the regional parts distribution center's inventory, then sends a signal to the manufacturer for the replenishment of part Z in its inventory.
Step 4	The manufacturer replenishes Company X's national parts distribution center inventory from finished goods inventory, then sends a signal to factory to make one part Z to replenish finished goods inventory.

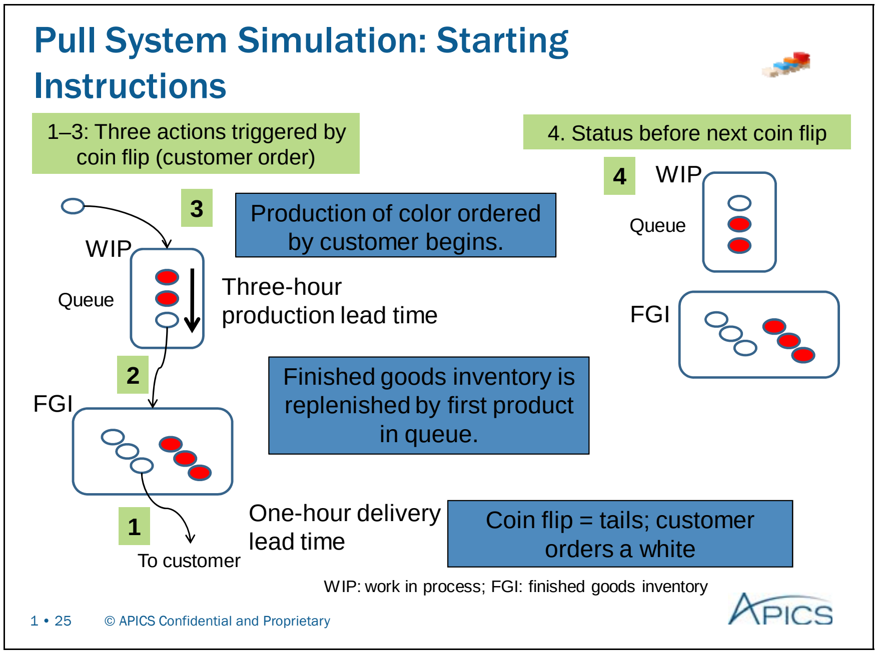
The manufacturer in this example carries part Z in inventory. This enables timely replenishment of Company X's national parts distribution center (for example, replenishment in one day) while it makes a replacement part Z, which might take two days.

The national distribution center also carries a day's supply of inventory (Z) because it knows it can be resupplied in one day from the manufacturer after replenishing the regional parts distribution center in one day.

What impact does the pull system have on inventory levels for part Z at the dealer and distribution centers?

____

____


Pull System Simulation: Starting Instructions
1–3: Three actions triggered by coin flip (customer order)
4. Status before next coin flip
3
Production of color ordered by customer begins.
WIP
Queue
Three-hour production lead time
2
Finished goods inventory is replenished by first product in queue.
FGI
1
To customer
One-hour delivery lead time
Coin flip = tails; customer orders a white
4
WIP
Queue
FGI
WIP: work in process; FGI: finished goods inventory
1 • 25
© APICS Confidential and Proprietary
APICS

Demonstration: Lean Pull System Simulation

Let's reinforce the pull model with a simulation that shows the mechanics of the pull system. In the example used, a manufacturer uses a pull system to meet customer demand for two models of the same product.

Starting procedures

The instructor will review the procedures to be used in this simulation of the basic pull system used in lean systems. The visual summarizes how a customer order (a coin flip) initiates

a. delivery of a product from finished goods inventory: red or white
b. replenishment of finished goods inventory by the first item in the WIP queue (this is the only finished item due to the three-hour production time)
c. start of production of the color ordered by the customer: either red or white.

The lead times are as follows:

- delivery to the customer from finished goods inventory: one hour
- production of a unit: three hours

The instructor will improvise the materials to be used in the simulation.

Simulation round 1

Working in pairs or small groups, start the simulation by flipping a coin. *Heads* means the customer has ordered a red model; *tails* means an order for a white model. Each coin flip represents a new order for one unit placed every hour.

Then, as shown in the visual:

1. Remove one product of the color ordered from finished goods inventory (delivery to customer).
2. Replenish finished goods inventory with the *first* product in the queue (color does not matter) that was the only finished item in the queue when the coin was flipped.
3. Place one product of the color ordered by the customer at the back of the queue in WIP. (This signifies start of production of a new model of the product that was just sold, which will take three hours.)

Continue to flip the coin and follow the procedure above to see if and when you will not be able to fulfill a customer order. Then answer the round 1 questions in Class Problem 1.2 on the next participant workbook page.

Simulation round 2

Continuing to work in groups, experiment with the impact of reduced WIP and finished goods inventory. Reduce the number of poker chips or coins (take away one, then two, and so on) in WIP and finished goods inventory. Correspondingly, reduce production lead time by one and then two hours, but maintain the one hour lead time to the customer. When the number of chips or coins can't be reduced further without affecting order fulfillment, then answer the round 2 questions in Class Problem 1.2.

Problem 1.2 Pull System Simulation

Simulation Round 1

1. Did you ever reach a stockout situation?
2. How many coin flips were necessary to make your determination?
3. What can you conclude about the need for finished goods inventory?

Simulation Round 2

1. What is the lowest level to which WIP and finished goods inventory (FGI) can be reduced and still achieve 100 percent customer service? Assume that production lead time is reduced first to two hours and then to one hour while maintaining a one-hour delivery lead time.
2. What assumption needs to be made about customer demand for this lean replenishment model to work?

1 • 26

Class Problem 1.2: Pull System Simulation

In pairs or small groups, answer the questions below after each round of the simulation.

Round 1

1. Did you ever reach a stockout situation?

2. How many coin flips were necessary to make your determination?

3. What can you conclude about the need for finished goods inventory?

Round 2

1. What is the lowest level to which WIP and finished goods inventory (FGI) can be reduced and still achieve 100 percent customer service? Assume that production lead time is reduced first to two hours and then to one hour while maintaining a one-hour delivery lead time.

2. What assumption needs to be made about customer demand for this lean replenishment model to work?

Problem 1.3 MRP and Lean Systems

Characteristics best suited to shop floor systems		
	Shop floor systems	
Market-facing characteristics	**MRP-based**	**Lean-based**
Product design		
Product variety		
Individual product volume/period		
Ease of changing total volume		
Ease of changing product mix		
Delivery speed		
Ease of changing delivery schedules		
Manufacturing-related characteristics		
Process choice		
Organizational control		
Work in process		

1 • 28

Class Problem 1.3: MRP-Based and Lean Shop Floor Systems

In pairs or groups, conclude the discussion of push and pull by identifying the market-facing (customer-facing) and manufacturing-related (internal-related) characteristics that are best suited to MRP-based and lean shop floor systems. In this problem, we have limited the MRP-based shop floor system to a job shop batch production environment. Referring to the pairs of terms below, complete the MRP-based and lean-based columns in the table. Be prepared to present some of your answers to the class.

Answer choices are below. (Use each pair of answers once.)

MRP-based	Lean -based
less difficult	more difficult
high	low
more difficult	less difficult
broad	narrow
low-volume batch	high-volume batch/line

MRP-based	Lean -based
custom	standard
centralized	decentralized
easy/incremental	difficult
through schedule change	through FGI
low	high

FGI: finished goods inventory

Characteristics best suited to shop floor systems		
Market-facing characteristics	Shop floor systems	
	MRP-based	Lean-based
Product design		
Product variety		
Individual product volume/period		
Ease of changing total volume		
Ease of changing product mix		
Delivery speed		
Ease of changing delivery schedules		
Manufacturing-related characteristics		
Process choice		
Organizational control		
Work in process		

Source: Jacobs, et al., *Manufacturing Planning & Control for Supply Chain Management*, APICS/CPIM Certification ed., copyright The McGraw-Hill Companies, Inc., chap. 17.